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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Werner REINHART	Examiner:	Pradeep C. Battula
Serial No.:	10/541,935	Art Unit:	3722
Confirm. No.:	8481	Docket No.:	1093-133 PCT/US
Filed:	July 8, 2005		
For:	SECURITY DOCUMENT COMPRISING AT LEAST ONE SECURITY ELEMENT		

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 CFR 1.132

I, Dr. Haymo Katschorek, state the following:

1. I am a co-inventor of U.S. Patent Application Serial No. 10/570,111, filed on March 1, 2006, along with Werner Reinhart, the inventor of the above-referenced patent application. Mr. Reinhart is deceased and I have been asked to submit this declaration in his place.

2. Beginning in 2001, I have worked in the Security Division of Leonhard Kurz GmbH & Co. for more than seven (7) years and conducted research and development relating to security elements similar to the security documents disclosed in the above-identified patent application. In my current position, I am a Project manager and Research Chemist in the Research and Development Group. I have extensive knowledge relating to the development and

manufacture of security elements and the materials that are used to form such devices. I have a masters degree and a doctorate in chemistry from Julius-Maximilians University in Wuerzburg, Germany. From 1999 through 2001, I worked as a scientific co-worker in the research group of the Coating Technologies Division at the "Fraunhofer-Institut fuer Silicatforschung" in Wuerzburg. My principal responsibility was the development of new barrier coatings for polymer films. Due to my work, I have developed extensive skills in lacquer formulations and polymer coatings.

3. I have read and understood the captioned patent application ("the present application"), the Office Action mailed on July 1, 2008 ("the Office Action") and U.S. Patent No. 5,582,103 to Tanaka et al. ("the `103 patent" or "Tanaka"). This declaration is being submitted in response to the Office Action to address findings made by the Examiner based on his interpretation of the `103 patent.

4. The `103 patent is directed to a method for making an anti-counterfeit latent image formed from various kinds of patterns including printed lines or halftone dots and relief patterns. Tanaka states at col. 3, lines 24-27 that: "Printing of the straight lines (2) is applied to the paper (4) using ink of a different color from that of the embossed paper (4). The printing method may be a conventional one, and offset printing is usually employed."

5. At page 3, lines 17-19 of the Office Action, the Examiner stated with respect to the `103 patent that: "Column 3, Lines 16-31; Figure 4, Items 1a, $2_5$ and $2_6$; Shows that a film is provided on the substrate in the form of an ink." I have reviewed the portions of the `103 patent

cited by the Examiner and I do not find any support for his finding that the ink printed on the substrate forms a film. Moreover, I do not find any disclosure or suggestion in the `103 patent which indicates that Tanaka considered the printing to be a film.

6. It is my opinion that one of ordinary skill in the art of anti-counterfeiting and security devices for documents and other valuable articles would not consider printing on the surface of a substrate to be a film. Based on my experience in the art, the commonly accepted definition of a film is a thin layer or sheet of material. Printing separate, unconnected lines on a substrate using ink as taught by Tanaka does not produce a thin layer or sheet of material.

7. The Office Action states at page 3, lines 20-22 that: "Column 3, Lines 12-31 [of the `103 patent]; teaches that the substrate is paper and the ink film is ink and it is inherent they have at least a different roughness." As stated above, I disagree with the Examiner's finding that the ink printed on the substrate in the `103 patent forms a film. I also disagree with the Examiner's finding that the paper and the ink printed on the paper inherently have a different roughness. Although the paper and the ink printed on the paper can have a different roughness, the difference in the roughness is not inherent and only occurs when specific printing processes are used. This is disclosed in the specification of the present application at page 4, line 30 to page 5, line 7 as follows:

> A further possible design configuration for the security document according to the invention provides that the substrate and the at least one surface region are formed by paper with markedly different surface properties which can be respectively detected by means of the human sense of touch. In that respect **the differing surface properties of the paper can be formed on the one hand by suitable printing thereon, for example by using special printing processes** which are

> known per se for the production of value-bearing papers or bonds. Another possible way is for the different surface properties of the paper to be produced by region-wise mechanical processing of the paper, in particular by roughening it, by embossing and/or glazing.
>
> (Emphasis added.)

I have reviewed the `103 patent and the only specific type of printing method that is disclosed is offset printing (col. 3, line 27 and col. 5, line 55). It is my opinion that offset printing does not necessarily produce a document wherein the paper and the ink printed on the paper have a different roughness. Therefore, it is also my opinion that the ink and the paper in the printing method disclosed in the `103 patent do not "inherently" have different roughness that could be detected by the human sense of touch as the Examiner has found.

8. The security device disclosed in the `103 patent is a latent image that uses surface irregularities and printing on the surface to generate different visual perceptions depending on the viewing angle. If the surface of the substrate is viewed orthogonally, all of the printing is clearly visible. However, if the substrate is viewed at an angle with respect to the surface, only certain parts of the printing are visible because the other parts are hidden from the viewer by the surface irregularities of the substrate.

9. It is my opinion that one of ordinary skill in the art of security elements would not find the `103 patent discloses or suggests the security document in the claims of the present application. The `103 patent teaches images formed by printing on a substrate that has closely spaced surface irregularities, but does not teach surface portions having different surface natures that can be distinguished by means of the human sense of touch.

10. It is also my opinion that one of ordinary skill in the art of security elements would understand the human sense of touch (as the term is used in the claims of the present application) refers to the sense of touch of an average person. Accordingly, the differences in the surface natures as used in the claims of the present application would have to be significant enough for them to be easily detected by a person with an average sense of touch. The detection of the differences in the surface natures would not require someone with a highly sensitive sense of touch. This is clearly disclosed in the specification of the present application at page 4, lines 18-23 which states:

> [A]t least one surface region comprises a different material from the substrate, in which respect advantageously the substrate and the at least one surface region are formed by different kinds of film **which differ markedly in properties** which can be detected by means of the human sense of touch. (Emphasis added.)

11. It is my opinion that the surface irregularities and the printing disclosed in the `103 patent are of such a kind and size that it would be almost impossible to detect the presence or absence of specific surface characteristics merely by the sense of human touch. The `103 patent discloses that the irregularities in the substrate and the printed lines are formed in patterns of 50 lines per inch. (See col. 3, lines 4-22.) This means that for each inch, if the lines and the spaces are approximately the same width, there are 50 lines and about 50 spaces between the lines so that the space between the lines is only about $^{1}/_{100}{}^{th}$ of an inch (i.e., about 0.254 mm wide). Moreover, as Figures 4, 6 and 7 of the `103 patent illustrate, the lines are printed on the irregular surface of the substrate so that they can be either on top of the irregularities (1a), between the irregularities (1a) or both. Therefore, it is my opinion that the very small distances

between the lines and the surface irregularities and the random printing of the lines on top of and in between the irregularities would make it very difficult, if not impossible, to distinguish differences in the surface characteristics of the substrate using the human sense of touch as required in the claims of the present application.

12. It is my opinion that the surface protrusions disclosed in the `103 patent are too closely spaced together to allow a person to distinguish the characteristics of different portions using the human sense of touch. The skin on the fingers is only flexible to a certain extent and, therefore, two protrusions on a surface cannot be distinguished if they are not spaced at least 0.5 mm apart. This has been reported in several studies including a book titled, "The Somatosensory System – Deciphering the Brain's Own Body Image," edited by Randall J. Nelson, PhD, CRC Press, 2002. The relevant disclosure is found in chapter 3, which contains an article titled, "Neural Mechanisms of Tactile Form and Texture Perception," by Kenneth O. Johnson and Takashi Yoshioka ("the Johnson and Yoshioka article"). A copy of the relevant portions of chapter 3 is attached hereto as Exhibit A.

13. At page 78 of the Johnson and Yoshioka article, the authors provide a graph showing that grating orientation discrimination (the filled squares on the graph) only occurs when the groove and ridge widths are at least 0.5 mm wide. In addition, the Johnson and Yoshioka article states in the first paragraph at the top of page 81 that: "humans cannot discriminate the orientation of an Optacon [OPtical to TActile CONverter] grating pattern until

the grooves in the grating exceed 5 mm width." I agree with these statements and find that they are consistent with my observations.

14. As I stated above in paragraph 11, the lines disclosed in the `103 patent are spaced about $^{1}/_{100}^{th}$ of an inch (or about 0.254 mm) apart. The findings in the Johnson and Yoshioka article confirm my opinion that the surface protrusions and the spaces between the protrusions that are disclosed in the `103 patent cannot be distinguished because they are not spaced at least 0.5 mm apart.

15. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the lie so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: October 15, 2008

H. Katschorek

Dr. Haymo Katschorek

300217_1

EXHIBIT A

THE SOMATOSENSORY SYSTEM

Deciphering the Brain's Own Body Image

Edited by Randall J. Nelson, Ph.D.

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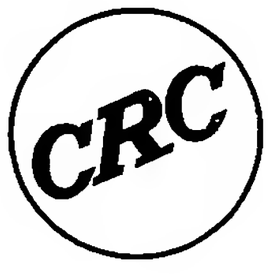
University of Tennessee Health Science Center
Memphis, Tennessee



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3 Neural Mechanisms of Tactile Form and Texture Perception

Kenneth O. Johnson and Takashi Yoshioka

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3.1 OVERVIEW

Information about the external world is analyzed and subdivided into separate processing streams in each of the sensory systems. That division begins at the very first stage of sensory processing within the somatosensory system: nociceptors, thermoreceptors, proprioceptors, and cutaneous mechanoreceptors transduce different stimulus properties and channel their information into separate, parallel streams. The same principle applies to the four cutaneous mechanoreceptors that are responsible for

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tactile perception. Evidence from three decades of psychophysical and neurophysiological research shows that each mechanoreceptive system (the mechanoreceptors of a single type and the pathways that convey their information to perception) serves a distinctly different function and that, taken together, these functions account for tactile perception (reviewed in Reference 1). In this chapter, we review briefly the functions of the mechanoreceptors, but we concentrate on the peripheral and cortical neural mechanisms of functions served by the slowly adapting type 1 (SA1) afferents (i.e., form and texture perception).

3.2 PERIPHERAL NEURAL MECHANISMS

3.2.1 MECHANORECEPTION

The four cutaneous mechanoreceptive afferent neuron types innervating the glabrous skin comprise SA1 afferents, which end in Merkel cells; rapidly adapting (RA) afferents, which end in Meissner corpuscles; Pacinian (PC) afferents, which end in Pacinian corpuscles; and slowly adapting type 2 (SA2) afferents, which are thought to end in Ruffini endings. Two of the four, the RA and PC afferents, respond only to skin motion; they are classed as rapidly adapting because they respond only transiently to sudden, steady indentation. The other two, the slowly adapting SA1 and SA2 afferents are classed as slowly adapting because they respond to sustained skin deformation with a sustained discharge that declines slowly, but they (particularly SA1 afferents) are much more sensitive to skin movement than to static deformation. The neural response properties of these cutaneous afferents have been studied extensively in both human and nonhuman primates and, except for the SA2 afferents, which are not found in nonhuman primates, there are no interspecies differences. We use the terms SA1, SA2, RA, and PC systems throughout this chapter.[2] By SA1 system, for example, we mean the SA1 receptors (the Merkel-neurite complex), the SA1 afferent nerve fiber population, and all the central neuronal pathways that convey the SA1 signal to memory and perception. We do not mean to imply that there is no central convergence between these systems or that the systems do not overlap.

SA1 afferent fibers branch repeatedly before they lose their myelin and end in the basal layer of the epidermis where specialized (Merkel) epidermal cells enfold the unmyelinated endings.[3] Although there are synapse-like junctions between the Merkel cells and the axon terminals, the transduction of local tissue deformation appears to arise as the result of the activation of mechanosensitive ion channels in the bare nerve endings.[4,5] SA1 afferents innervate the skin of the fingerpad densely and have small receptive fields. Consequently, they transmit high resolution spatial neural images of stimuli contacting the fingerpad. A striking response property is surround suppression,[6] which gives SA1 afferents response properties like those attributed to surround inhibition in the central nervous system. In the central nervous system, inhibition surrounding an excitatory center makes neurons sensitive to local curvature and, depending on the balance between excitation and inhibition, insensitive to a uniform stimulus field. Surround suppression in the responses of tactile peripheral afferents confers similar response properties but instead of being based

on synaptic mechanisms it is based entirely on mechanoreceptor sensitivity to a specific component of tissue strain near the nerve ending (strain energy density or a closely related component of strain[7,8]). As a consequence, SA1 afferents respond strongly to points, edges, and curvature and these responses are suppressed by the presence of stimuli in the surrounding skin. Also, because of this surround suppression, SA1 afferents are minimally responsive to uniform skin indentation. Therefore, local spatial features such as edges, and curves are represented strongly in the neural image conveyed by the peripheral SA1 population response (illustrated in Figure 3.3). Combined psychophysical and neurophysiological experiments, reviewed below, show that the SA1 system is responsible for form and texture perception.

RA afferent fibers also branch repeatedly as they near the epidermis, ending in 30–80 Meissner's corpuscles.[1] Meissner's corpuscles occur in dermal pockets between the sweat-duct and adhesive ridges,[9,10] which puts them as close to the surface of the epidermis as possible within the dermis.[11] This may account, in part, for the RA's greater sensitivity to minute skin deformation compared with SA1 afferents, whose receptors are on the tips of the deepest epidermal ridges. RA afferents innervate the skin of the fingerpad more densely than do the SA1 afferents. Based on the available studies of innervation density,[12-14] Johnson et al.[1] have concluded that innervation densities in humans and monkeys are not significantly different and that the best estimates at the fingertip are 100 SA1 and 150 RA afferents/cm^2. Although RA afferents have a greater potential for transmitting spatial information because of their greater innervation density, they resolve spatial detail poorly. Their receptive field sizes depend strongly on stimulus intensity and are much larger than SA1 receptive fields at indentation levels that occur in ordinary tactile experience.[15] The striking feature of RA responses is their sensitivity to minute skin motion. The effective operating range for RAs is about 4–400 μm indentation; the comparable SA1 range is about 15–1500 μm or more.[15,16-18] The SA1 and RA response properties are complementary. The RA and SA1 systems are, in some ways, like the scotopic and photopic systems in vision. The RA system, like the scotopic system, has greater sensitivity but poorer spatial resolution and limited dynamic range. The SA1 system, like the photopic system, is less sensitive but has higher spatial resolution and operates over a wider dynamic range. The neural response properties of RA afferents make them ideally suited for motion perception. In fact, combined psychophysical and neurophysiological studies show that the RA system is responsible for the perception of events that produce low-frequency, low-amplitude skin motion. That includes the detection of microscopic surface features, the detection of low frequency vibration, and the detection of slip, which is critical for grip control (reviewed in Reference 1).

PC afferent fibers end in single Pacinian corpuscles, which occur in the dermis or the deeper tissues. Bell, Bolanowski and Holmes[19] have provided an extensive review of the history, structure, and electrophysiological properties of this receptor. The PC's most striking property is its extreme sensitivity, which derives from mechanosensitive ion channels in the afferent's unmyelinated ending. The most sensitive Pacinian corpuscles respond with action potentials to vibratory amplitudes as small as 3 nm applied directly to the corpuscle[20] and 10 nm applied to the skin.[21]

Pacinian corpuscles comprise multiple layers of fluid-filled sacs; these sacs act as a cascade of high-pass filters that shield the unmyelinated ending from the large, low frequency deformations that accompany most manual tasks.[22,23] If it was not for this intense filtering, the transducer, which is two orders of magnitude more sensitive than any of the other mechanoreceptive transducers, would be overwhelmed by most cutaneous stimuli. Because of their extreme sensitivity, receptive field boundaries are difficult to define. The most sensitive PCs have receptive fields that encompass an entire hand or even an entire arm; a less sensitive PC may have a receptive field restricted to a single phalanx. There are about 2500 Pacinian corpuscles in the human hand and they are about twice as numerous in the fingers as in the palm (about 350 per finger and 800 in the palm; reviewed in Reference 21). Because of the small number of PC afferents and their very large receptive fields, the PC population transmits little, if any useful information about the spatial properties of a stimulus. Instead, it transmits information communicated by vibrations in objects, probes, or tools held in the hand (reviewed in Reference 1).

SA2 afferents are distinguished from SA1 afferents by four properties: (1) their receptive field areas are about five times larger and their receptive field borders are not clearly demarcated;[24] (2) they are about six times less sensitive to cutaneous indentation;[25,26] (3) they are 2–4 times more sensitive to skin stretch;[27] and (4) their interspike intervals are more uniform.[27,28] SA2 afferents are thought to end in Ruffini complexes,[3] although the association of afferents with these response properties with a specific receptor is not as secure as with the other three cutaneous mechanoreceptors. Both SA1 and SA2 afferents respond to forces orthogonal and parallel to the skin surface, but between them the SA1 afferents are biased toward responsiveness to orthogonal forces and SA2 afferents to parallel forces.[29] The minimal SA2 responses to raised dot patterns (e.g., Braille patterns in Figure 3.4) and to curved surfaces[30] suggest that they play no role in form perception.[31] Based on their responses to curved surfaces, Goodwin et al. conclude that "SA2 responses are unlikely to signal information to the brain about the local shape of an object" (page 2887 in Reference 30). Because of their sensitivity to skin stretch, SA2s are well suited to signal lateral forces such as active forces pulling on an object held in the hand. A more interesting possibility is that they send a neural image of skin stretch that plays a significant, or possibly even the dominant, role in our perception of hand conformation (reviewed in Reference 1) and of the direction of motion of an object moving across the skin.[32]

3.2.2 Form and Texture Perception

Form and texture perception have in common only that both depend on surface structure. Form perception is perception of the specific geometric structure of a surface or object; texture perception corresponds to the subjective feel of a surface and it depends on its distributed, statistical properties. Form perception has many dimensions; texture perception has only two or possibly three dimensions (see below). Form perception can be studied with objective methods (i.e., the subject's responses can be classified as right or wrong); texture perception cannot. If a subject

TABLE 3.1
Afferent Types and Their Functions

Afferent Type	Receptor	Adaptation to Steady Deformation	RF Size	Spatial Resolution	Temporal Sensitivity (Hz)	Function
SA1	Merkel	Slow	Small	0.5 mm	0–100	Form, texture
RA	Meissner	Rapid	Small	3–5 mm	2–100	Motion perception, grip control
PC	Pacinian	Rapid	Large	2 cm	10–1000	Transmitted vibration, tool use
SA2	Ruffini	Slow	Large	1 cm	0–20	Lateral force, hand shape, motion direction

is asked whether the dot or ridge spacing of one surface is greater than another the response is a judgment about the surface and it provides a clue to the subject's capacity for form perception (e.g., Reference 33 and 34); if the same subject is asked whether the second surface feels rougher (or softer) than the first, the response is a description of his or her experience and it provides a clue to the subject's perception of texture.

3.2.2.1 Form Perception

The ability to discriminate object or surface features and the capacity for pattern recognition at the fingertip are the same whether the object is contacted by active touch or is applied to the passive hand.[35] Form perception is affected only marginally by whether the object is stationary or moving relative to the skin; it is unaffected by scanning speed up to 40 mm/s; it is unaffected by contact force, at least over the range from 0.2–1 N; and it is affected only marginally by the heights (relief) of spatial features over a wide range of heights.[36-39]

Three psychophysical studies of the limit of tactile spatial acuity are illustrated in Figure 3.1. In all three studies, the element width that resulted in performance midway between chance and perfect discrimination was between 0.9 and 1.0 mm, which is close to the theoretical limit set by the density of SA1 and RA primary afferents at the fingertip.[40] Acuity declines progressively from the index to the fifth finger[41] and it declines progressively with age.[42-44] Whether these differences in acuity are due to differences in innervation density is not known. Spatial acuity at the fingertip is the same in man and monkey.[45] Spatial acuity at the lip and tongue is significantly better than at the fingertip.[46-48]

3.2.2.1.1 Spatial Acuity

Tactile spatial resolution of about 1 mm requires an innervation density of (at least) about one afferent per square mm and it requires that individual afferents resolve the spatial details at least as well as human subjects. Neither the PC nor the SA2 system comes close on either score.[13,49] Note that the human performance illustrated

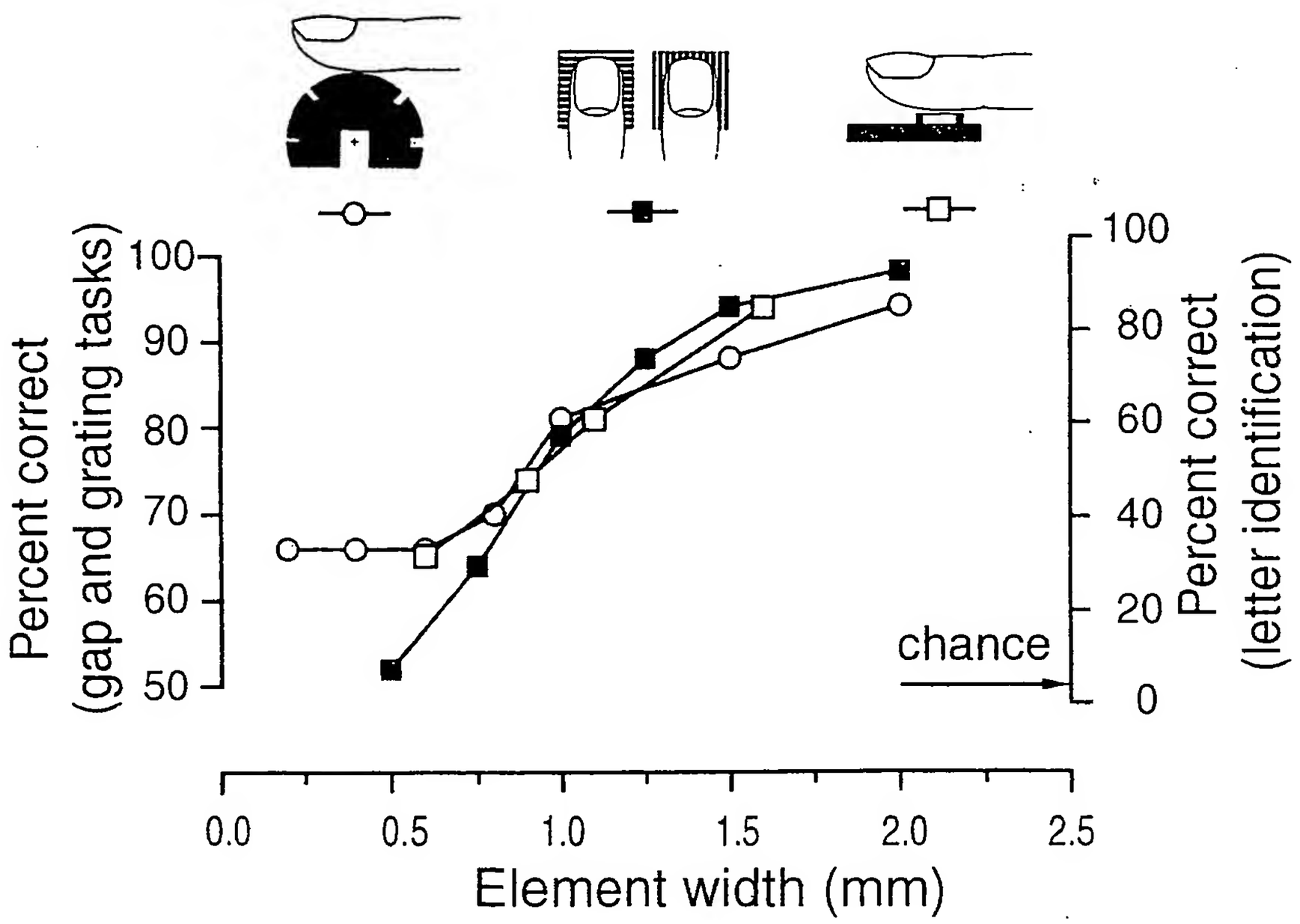

FIGURE 3.1 Human performance in gap detection (open circles), grating orientation discrimination (filled squares), and letter recognition (open squares) tasks. The abscissa represents the fundamental element width for each task, which was gap size for the gap detection task, bar width (half the grating period) for the grating orientation discrimination task, and the average bar and gap width within letters (approximately one fifth the letter height) for the letter recognition task. Threshold is defined as the element size producing performance midway between chance (50% correct for the gap and grating tasks, 1/26 for letter recognition) and perfect performance. Adapted from Johnson, K.O. and Phillips, J.R., *J. Neurophysiol.* 46, 1177–1191, 1981, with permission.

in Figure 3.1 begins to rise above chance at element sizes around 0.5 mm, which means that either the SA1 or RA system must begin to resolve spatial detail at 0.5 mm or less. Evidence that only the SA1 afferents account for the spatial resolution illustrated in Figure 3.1 comes from neurophysiological experiments in which SA1 and RA afferents were studied with the same periodic gratings used in the psychophysical experiments. SA1 responses to a periodic grating convey information about spatial structure when the groove and ridge widths are 0.5 mm wide (e.g., see Figure 3.2). When the grooves and ridges are 1 mm wide, SA1s provide a robust neural image of the stimulus. In contrast, RAs require grooves that are at least 3 mm wide before their responses begin to distinguish a grating from a flat surface; most RAs fail even to register grooves 3 mm wide.[7] The RA response illustrated in Figure 3.2 was the most sensitive to spatial detail of all the RAs studied. Kops and Gardner[50] obtained nearly identical results with an Optacon, a dense array of vibrotactile probes designed as a reading aid for the blind.[51] PC afferents were unable to resolve grooves that were 5 mm wide (Figure 3.2).

3.2.2.1.2 Pattern Recognition

The relationship between SA1 response properties and pattern recognition behavior in a letter recognition experiment is illustrated in Figure 3.3. In the study illustrated in Figure 3.3, Vega-Bermudez et al.[35] showed that there was no detectable difference in human performance between active and passive touch and that the confusion matrix shown in Figure 3.3 is characteristic of human letter recognition performance across a wide range of stimulus conditions. Recognition behavior is highly pattern specific; recognition accuracy differs significantly between letters (ranging from 15% for the letter N to 98% for the letter I) and more than 50% of the confusions are confined to 7% of all possible confusion pairs (22 out of 325 possible confusion pairs), which are enclosed in boxes in Figure 3.3. The confusions in all but 5 of those 22 pairs are highly asymmetric ($p < 0.001$). Analysis of the hit rates and false positive rates suggests that this recognition behavior bears no relationship to cognitive bias. The frequency of occurrence of letters in English bears no relationship to the rates of correct responses, false positives, or total responses. Further, if the recognition behavior illustrated in Figure 3.3 was related to cognitive biases, the hit rates and false positive rates should be related but they are not.[35]

The responses of SA1 afferents to the same letters scanned across their receptive fields (Figure 3.3) seem to explain the recognition behavior. For example, B is rarely identified as B; instead, it is called D more often than it is called B. Conversely, D is virtually never called B (Figure 3.3 top). The reason for this response bias can be explained by the SA1 surround suppression mechanism discussed earlier, which suppresses the response to the central, horizontal bar of the B: the neural representation of the B does, in fact, resemble a D more than it does a B (see Figure 3.3). For another example, C is often called G or Q, but G and Q are almost never called C. An explanation is that many of the features that discriminate the letters are missing in the neural representations, so a lack of the features that distinguish a G or Q from a C in the representation of the C is not a strong reason to not respond G or Q. Conversely, the strong representation of the distinctive features of the G and Q make confusion with a C unlikely. The performance illustrated in Figure 3.3 is for naive subjects in their first testing session. Performance improves steadily on repeated testing.[35] One explanation for this improvement is that subjects learn the idiosyncracies of the neural representations (e.g., when a subject recognizes the distinctive feature of the G in the neural representation he or she is less likely to mistake a C for a G).

The responses of typical human cutaneous afferents to Braille symbols (top row) scanned over their receptive fields are illustrated in Figure 3.4. The human SA1, RA, and PC responses to these raised-dot patterns are indistinguishable from the responses of monkey SA1, RA, and PC afferents to similar patterns.[36] SA1 afferents provide a sharp, isomorphic representation of the Braille patterns, RA afferents provide a less sharply defined isomorphic representation, and PCs and SA2s provide no useful spatial information.

3.2.2.1.3 Studies with the Optacon

Psychophysical and neurophysiological studies with the Optacon provide a unique window on tactile perception in the absence of activity in the SA1 system. Neurophysiological studies show that the Optacon activates the RA and PC systems

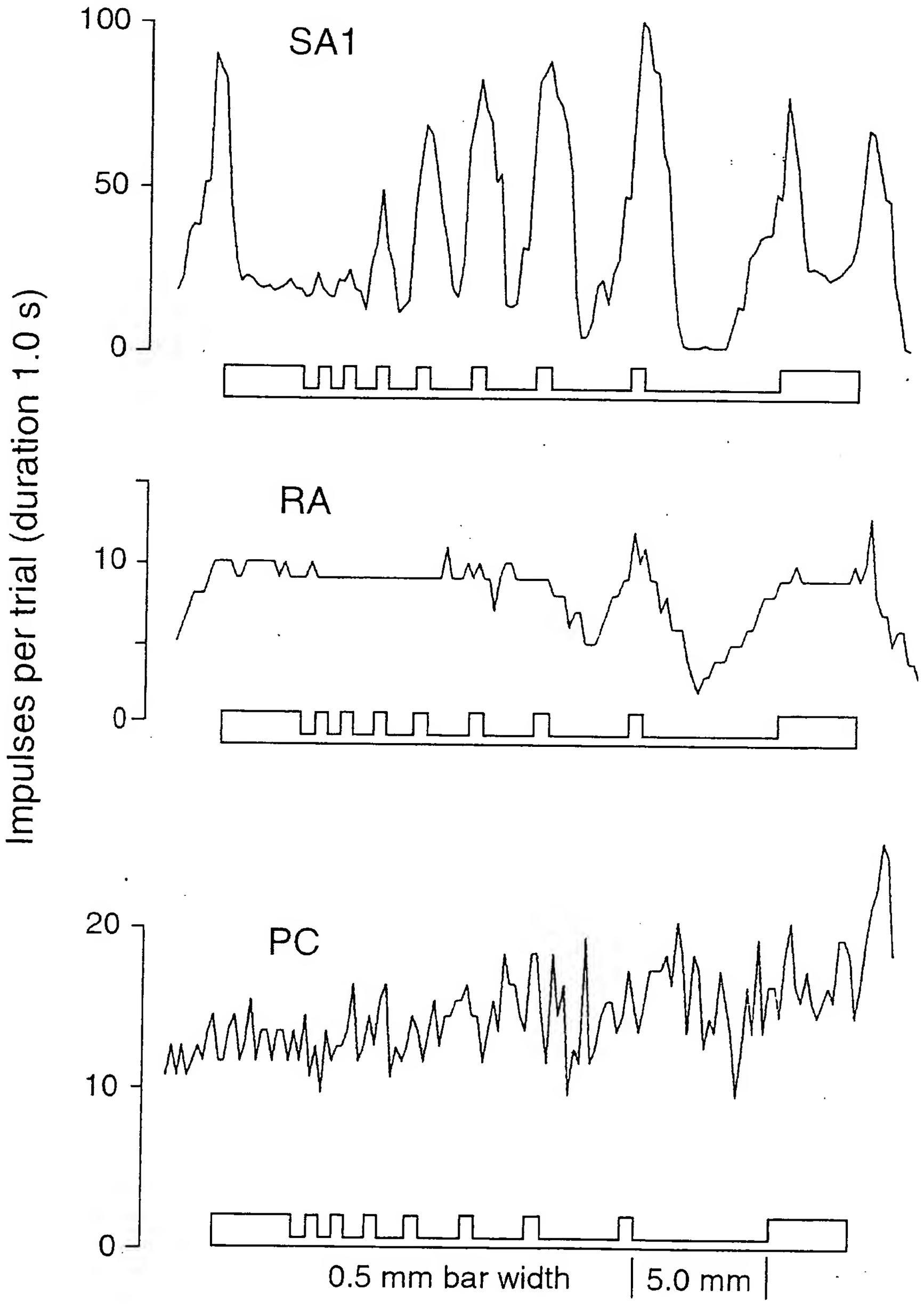

FIGURE 3.2

well, that it fails to activate the SA1 system, and that the PC system cannot account for spatial pattern recognition performance with the Optacon;[52,53] therefore, the many psychophysical studies employing the Optacon[54] are studies of the sensory capacity provided by the RA system. The human ability to resolve spatial patterns with the

Optacon is exactly that which would be predicted based on the RA responses illustrated in Figure 3.2. For example, humans cannot discriminate the orientation of an Optacon grating pattern until the grooves in the grating exceed 5 mm width.[50] This implies that the SA1 system is solely responsible for the limits of resolution illustrated in Figure 3.1.

3.2.2.1.4 Curvature Perception

Combined psychophysical and neurophysiological studies of curvature perception provide evidence of the neural mechanisms of form perception not based on the limits of spatial acuity.[55-58] These studies by Goodwin, Wheat, and their colleagues show that estimates of curvature are unaffected by changes in contact area and force and, conversely, estimates of force are unaffected by changes in curvature. This latter finding is particularly surprising considering that SA1 firing rates are strongly affected by curvature.[58,59,60] These psychophysical observations (that curvature perception is unaffected by changes in contact area or force) suggest that the spatial profile of neural activity in one or more of the afferent populations is used for the perception of curvature and that a different neural code (e.g., total discharge rate) is used for the perception of force. Only the SA1 population response provides a veridical representation of curvature that can account for the psychophysical observations.[58,61] The SA1 population responses to a wide range of curvatures are shown in Figure 3.5. RAs respond poorly to such stimuli and provide no signal that might account for the ability of humans to discriminate curvature.[58,62,63]

3.2.2.2 Texture Perception

Our knowledge of texture perception and its neural mechanisms has changed dramatically in the last decade. A major step is the demonstration that texture perception involves two strong dimensions, roughness and softness, and a weaker third dimension described as something like stickiness. Multidimensional scaling studies have shown that texture perception includes soft–hard and smooth–rough as independent perceptual dimensions, surface hardness and roughness can occur in almost any combination, and that they account for most or all of texture perception.[64,65] A third,

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FIGURE 3.2 (opposite) Responses of SA1, RA, and PC afferents to a grating pressed into the skin. The grating is shown in cross section beneath each response profile. The bars are 0.5 mm wide; the grooves are deeper than illustrated (2.0 mm deep) and are 0.5, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, and 5.0 mm wide. The responses displayed in each profile were obtained by indenting the skin to a depth of 1 mm, holding the indentation for 1 second, raising the grating, and then moving it laterally by 0.2 mm before the next indentation. The horizontal dimension of the response profile represents the location of the center of the receptive field relative to the grating; for example, the left peak in the SA1 response profile (approximately 95 imp/s) occurred when the center of the SA1 receptive field was directly beneath the left edge of the grating. The RA illustrated here was the most sensitive to the spatial structure of the grating of all RAs studied. Some RAs barely registered the presence of the 5 mm gap even though they responded vigorously at all grating positions. Adapted from Phillips, J.R. and Johnson, K.O., *J. Neurophysiol.* 46, 1192–1203, 1981, with permission.